Effect of Irradiation on the Superconductor Properties of $Bi_2 Sr_{2-x} Li_x Ca_2 Cu_3O_y$

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Abstract

High temperature superconductor $Bi_2 Sr_{2-x}Li_x Ca_2Cu_3O_y$ was prepared by a solid state reaction method, with firing temperature 800 ^oC for 24 hours and sintering temperature 850 ^oC for 140 hours. Superconductor properties studied before and after irradiation, critical temperature and oxygen content increases by increasing of ratio of Li (Li=0.1, 0.2, 0.3), but its decrease after irradiation.

X-ray diffraction analysis showed that the compounds have two phases: high-T_c phase (2223) and low-T_c phase(2212) in addition to impurity phase, also irradiation lead to decreases volume fraction of high-T_c phase (2223) and appear new peaks.

Scanning electron microscope has been used to evidence the morphology of the superconductor phases. Grain size increases by increasing of Li concentration and these grains take square-shaped, but after irradiation grain size becomes smaller and square -shaped disappear.

الخلاصة

حضرت نماذج من ألمركب $Bi_2 Sr_{2-x}Li_x Ca_2Cu_3O_y$ ألفائق ألتوصيل بطريقة تفاعل ألحاله ألصلبه وبدرجة حرارة حرق^oC 800 لمدة 24 ساعة وبدرجة حرارة تلبيد ^oC 850 لمدة 140 ساعة، درست خواص ألموصل ألفائق قبل وبعد ألتشعيع، أظهرت تحليلات ألاشعه ألسينيه إن ألمركب يمتلك طورين: ألطور فائق ألتوصيل ألعالي (2223) والطور فائق التوصيل الواطئ (2212) بالإضافة إلى طور الشوائب، كذلك وجد أن ألتشعيع يؤدي إلى تقليل النسبة ألحجميه للطور فائق التوصيل العالي (2223) وظهور قمم جديدة.

لقد استخدم المجهر الالكتروني الماسح لدراسة تشكيلة الأطوار فائقة التوصيل وقد وجد ان الحجم الحبيبي يزداد بزيادة تركيز ألليثيوم وهذه الحبيبات تكون مربعة الشكل ولكن بعد التشعيع يصبح الحجم الحبيبي اصغر ويختفي الشكل المربع للحبيبات.

Introduction

Superconductors are materials whose resistance is zero below a certain temperature, called the critical temperature(T_c) (Maqsood and Maqsood,1996), this material including simple elements, metallic alloys and certain ceramic compounds, these compounds known as the cuprate high temperate superconductor (Hott *et al.*, 2004).

Based on the number of CuO_2 planes in the characteristic multilayer blocks, the high critical temperature cuprate superconductors can be classified into: single layer materials [e.g.,$Bi_2Sr_2CuO_{6+\delta}$(Bi2201)], bilayer materials [e.g.,Bi_2Sr_2Ca-$Cu_2O_{8+\delta}$ (Bi2212)] and trilayer materials [e.g.,$Bi_2Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi2223)] (Damascelli *et al.*, 2002). This structural characteristic has a direct correlation with the superconducting properties: within each family of cuprates, the super-conducting phase transition temperature (T_c) first increases with the layer number (n) (Bernhard *et al.*, 2004). Because of the highest critical temperature, the (2223) phase of the compound has attracted greater interest and many workers have spent much effort to obtain the pure phase of the compound in the bulk, this phase has unstable structure (Ertan and Necdet, 2001). Intergrowth of multiple phases in crystal grain has posed difficulties in preparing single phase crystals (Shaoyan and Michal, 1998).

These compound are very important practical applications, therefore we suggested that study the effect of gamma radiation on the superconductor properties.

Experimental Procedure

The samples were prepared by standard solid state reaction from the starting materials Bi_2O_3, $Sr(No_3)_2$, $LiCo_3$, $CaCo_3$ and CuO. These were mixed and the mixture was thoroughly ground in an agate mortar and then calcined at 800 ^oC for 24 hours in a furnace to remove CO_2 and NO_2 gases from the mixture.

The calcined powder was reground again, pressed to pellets with (1.2cm) in diameter under a hydrostatic pressure about (0.5Gpa).The pellets were sintered at 850 ^oC for 140 hours. The pellets were examined by Miessner effect to evaluate the superconducting state.

Oxygen content in the samples was determined by idometric titration method, these method include: weighting (45mg) of sample and placed inside a conical

flaks on the magnetic stirrer, adding (2.5ml) of KI solution and (1.25ml) of HCl solution are added together to the samples powder, the liquid in the flask turns dark brown, the solution of $Na_2S_2O_3$ is added to the liquid from the burette when the liquid becomes pale brown a few drops of starch were added. The liquid turns dark blue, further addition of the $Na_2S_2O_3$ solution with more slowly will turn the liquid to yellow. Stopped the titration and measured the volume of the titrated $Na_2S_2O_3$ solution, and oxygen content (δ) could be found from equation (Swinnea *et al.*, 1987).

$$\delta = \left(\frac{M_A}{M_B} - \frac{3m_A}{C\,V}\right) / \left(\frac{2m_A}{C\,V} - \frac{M_0}{M_B}\right) \qquad (1)$$

where M_A is the molar mass of the sample, m_B molar masses of $Na_2S_2O_3 .5H_2O$, m_A weight of the sample, C concentration of the $Na_2S_2O_3$, V volume of $Na_2S_2O_3$ used in titration and M_O atomic weight of oxygen.

The phase compositions of samples were analyzed by X-ray diffraction analysis using Cu-Kα radiation. The electrical properties were measure by four-point probe method, in the temperature intervals of (77-300) K and direct current from 0.5mA to 15mA was admitted throw the sample. The resistivity could be found from the relation (Sorab, 1968).

$$\rho = \frac{V\,W\,t}{I\,L} \qquad (2)$$

where I is the current passing throw the sample, V the voltage drop across the electrodes, W width of the sample, t thickness of the sample and L the effective length between the electrodes. The microstructure of the sample was observed using a scanning electron microscopy (SEM); the observation was performed on the surface of the samples.

Samples have been irradiated by gamma ray at room temperature by using Co^{60}, the test samples were irradiated dose 23MRad, all these samples have been examined before and after irradiation.

Results and Discussion

The values of excess oxygen content are shown in Table (1). It could be noted that the value of excess oxygen content (δ) of the specimens doping with lithium gradually increases because of the doping introduce additional oxygen in to the Li/Sr-O planes. After irradiation the amount of oxygen is decreases because irradiation act on the damage the bonds in the CuO planes and consist of defects, these defects decreases the number of holes in the lattice (Bodi *et al*., 2001).

Table (1). Oxygen content of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ before and after irradiation**.**

x	Oxygen content	
	Before irradiation	After irradiation
0.1	0.213	0.184
0.2	0.259	0.215
0.3	0.324	0.273

On the other hand, the critical temperature of the prepared sample increasing by increasing of lithium concentration (T_c=102,110,120)K when (x=0.1,0.2,0.3) respectively, as shown in figure (1) before irradiation, apparently it is due to the fact that, for small hetrovalent replacement of 2-valent copper cation by 1-valent lithium ion, the concentration of Cu^{+3} holes in the CuO_2 layers increases (Meretliev *et al*., 200).The critical temperature of the samples decreased after irradiation, where taken the values (T_c=93,102,109)K when (x=0.1,0.2,0.3) respectively, see figure (2), due to change in oxygen stoichemetry, also this may be attributed to the radiation induce damage of weak links which result in poor grain conductivity in Bi-2223 compound (Borisenko *et al.*,2006).

Figure (3) shows x-ray diffraction of the prepared samples before irradiation, we could be seen from the spectra that two phases in all samples: high-T_c phase (2223), low-T_c phase and a small amount of impurity phases. The substitution of Sr by Li may well relax the modulation by influencing the charge balance oxygen content and structure of the relevant layers (Mazaki *et al.*, 2005), from these figure can be noticed that the high rate of (2223) phase appears with increasing Li content and slightly change in the intensity. Figure (4) shows x-ray diffraction of irradiated samples, from this figure observe the volume fraction of high-T_c phase decreasing and the irradiation cause shifted of peaks, as well as some oxide impurities were found to be developed peaks corresponding to another oxide impurities which may be attributed to the absent of some oxygen atoms due to irradiation (Kivelson *et al.*, 2006).

Figure (5) shows SEM photographs of samples before irradiation. It can be observed from figure (5a) plate-link grains which consist of 2212 phase and grain boundaries are very clean. From figure (5b) we can see that some small particles are seen on the edge of the plate-like, the size and amount of particle increase and the shape of these particles is square (figure (5c)) (Guo, *et al*., 2000).

Figure (6) shows SEM of irradiated samples, from this figure we can see these particles become smaller and less continuously and the square shaped particles disappeared (Ramesh, 2005).

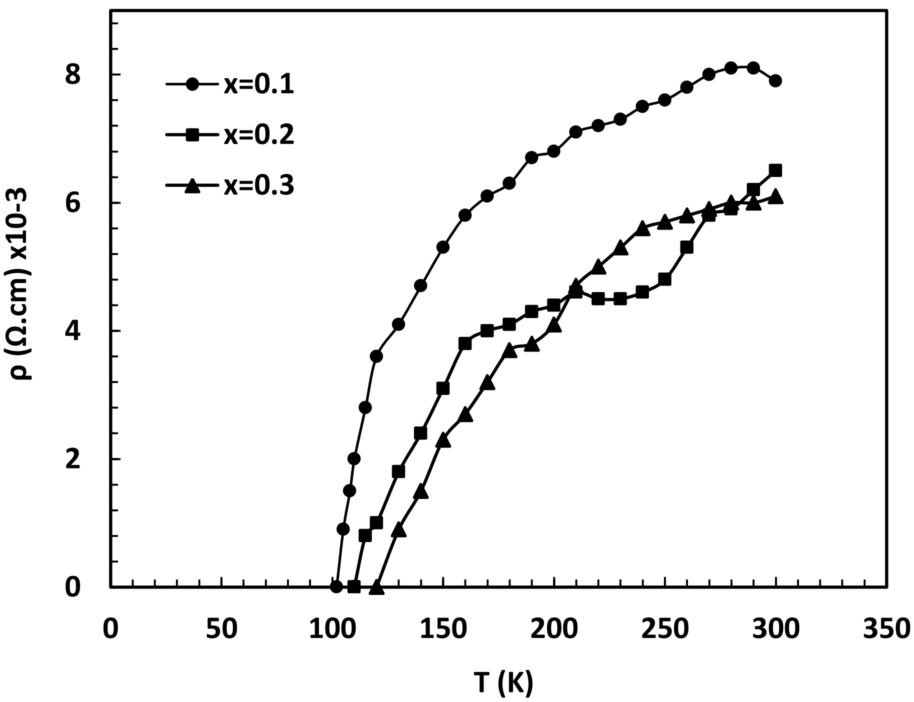


Figure (1). Temperature dependence of resistivity of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ before irradiation

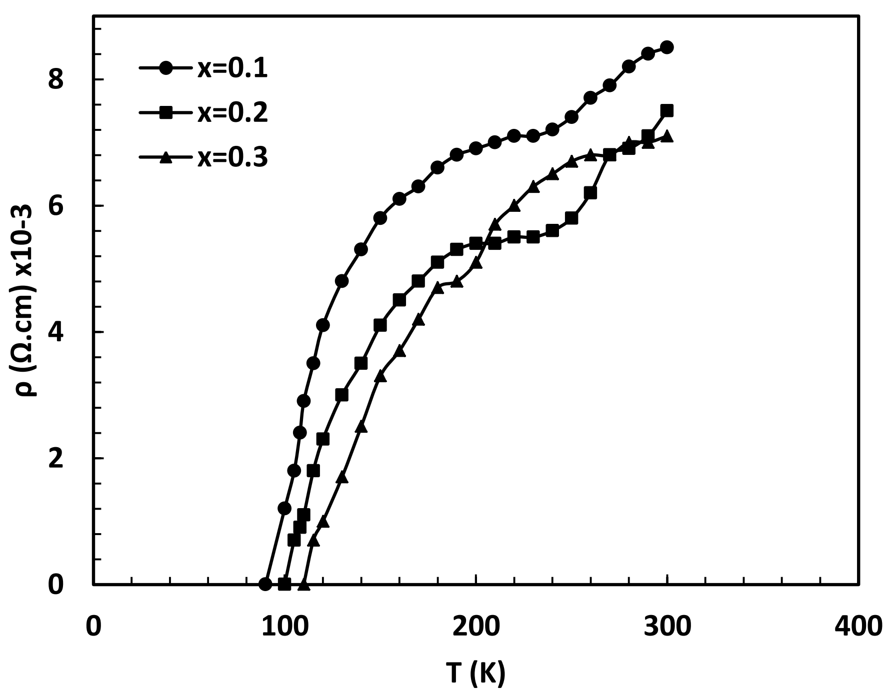


Figure (2). Temperature dependence of resistivity of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ after irradiation

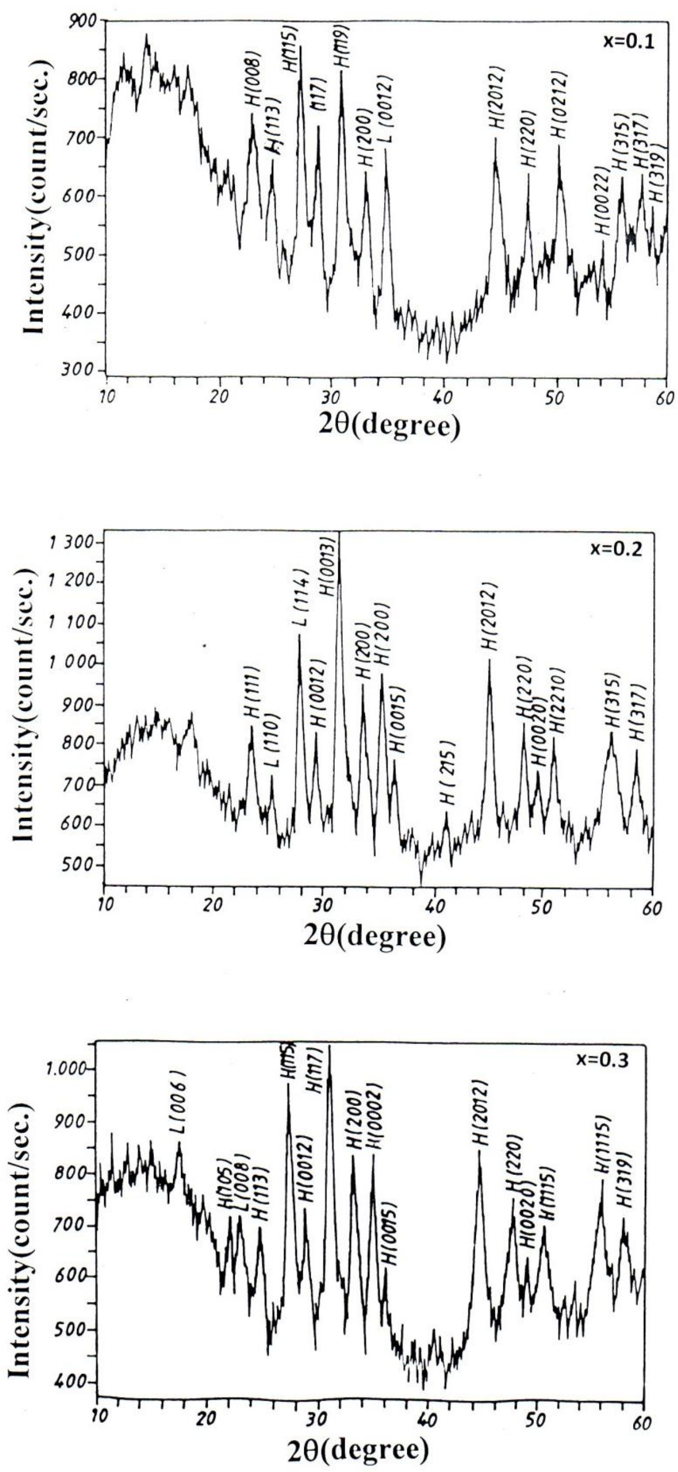


Figure (3). X-ray diffraction of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ before irradiation.

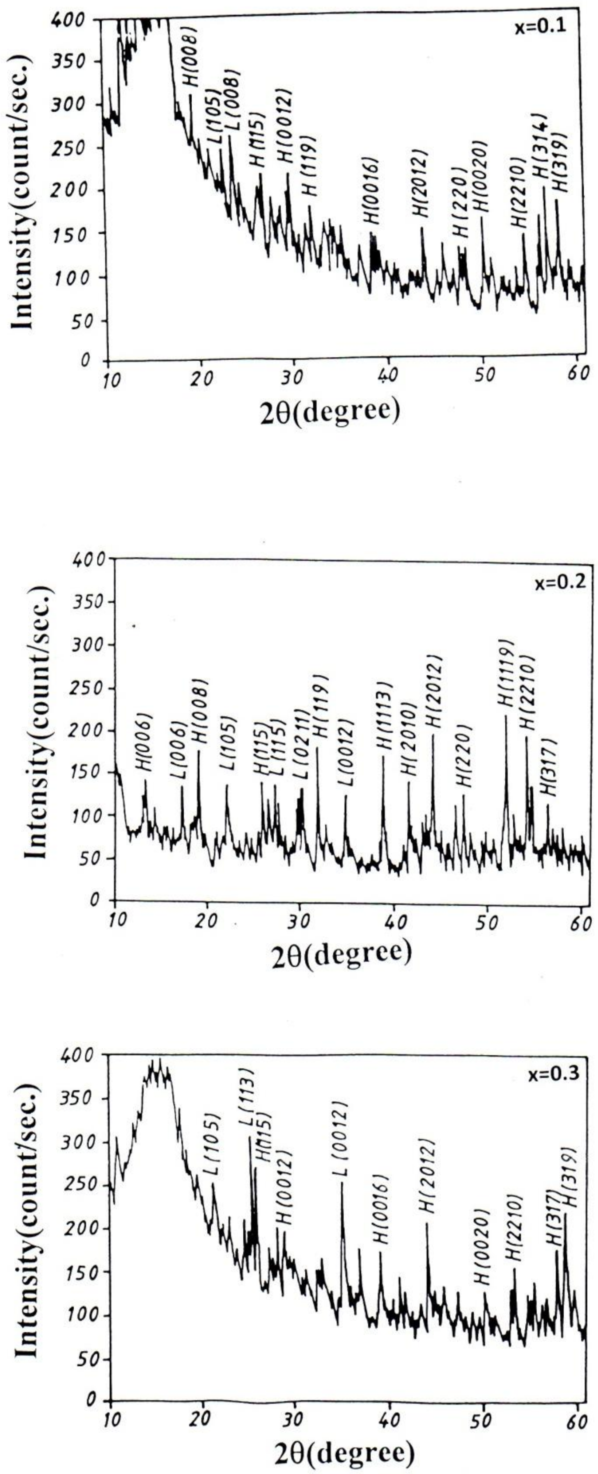


Figure (4). X-ray diffraction of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ after irradiation.



a



b



c

Figure(5). SEM of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ before irradiation.



a



b



c

Figure(6). SEM of $Bi_2Sr_{2-x}Li_xCa_2Cu_3O_Y$ after irradiation.

Conclusions

The critical temperature increases by increasing of Li, also excess oxygen content, while its decreasing for irradiated samples, as well as irradiation leads to decreasing in volume fraction of high-T_c phase with appearing of new peaks of impurity oxide phases. Scanning electron microscope obvious plate-like grains which consist of (2212) phase and the shape of particles is square but these particles become small and the square-shaped faded after irradiation.

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